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Technical Report ECOM-01698-10

LONG-LIFE COLD CATHODE STUDIES FOR CROSSED-FIELD TUBES

PROGRESS REPORT

by

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JULY 1968

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

Contract DA28-043-AMC-01698 (E)

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RAYTHEON COMPANY

MICROWAVE AND POWER TUBE DIVISION

Waltham, Massachusetts

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Prepared by

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For

U.S. Army Electronics Command
Fort Monmouth, N.J. 07703

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ABSTRACT

Further tests of the effects of high current-density electron bombardment (0.75 A/cm^2) and of residual oxygen (~1.5 x 10^{-5} Torr) on the secondary emission ratio (δ) were performed in the Electron Bombardment Vehicle (EBV). δ_{max} for a 300Å electron-beam-evaporated layer of alumina on molybdenum increased from 2.0 to 3.8 due to O_2 pressure of 1.5 x 10^{-5} Torr, and decreased from 3.8 to 2.0 due to 0.75 A/cm^2 electron bombardment without oxygen. δ_{max} for an anodized beryllium target (300A oxide layer) increased from 1.9 to 3.0 under the same O_2 treatment.

Operation of the QKS1397 CFA test vehicle for more than 200 hours has shown that the available emission (using the O_2 dispenser) from an evaporated aluminum-on-copper cold cathode appears to have stabilized near a peak current of 40 amperes (~2 A/cm^2) at a 0.002 duty factor. Approximately 70 hours of operation were obtained at 2.5 A/cm^2.

FOREWORD

Long-life cold cathode studies for crossed-field tubes are authorized by the United States Army Electronics Command, Fort Monmouth, New Jersey, under DA Project No. 7900-21-223-12-00. The work was prepared under the support of the Advanced Research Projects Agency under Order No. 345 and is conducted under the technical guidance of the U. S. Army Electronics Command, Fort Monmouth, N. J. 07703.

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1. INTRODUCTION

The objective of the present cold cathode study program is to achieve long life cold-cathode performance for crossed-field amplifiers. This program is being performed for the United States Army Electronics Command, Fort Monmouth, New Jersey, under contract DA-28-043-AMC-01698(E).

In this study, selected cold cathode materials will be evaluated as to their secondary emission properties, their ability to withstand environmental factors expected in a crossed-field amplifier, and their crossed-field amplifier performance. Based on the above experimental information and pertinent theoretical calculations, a life prediction chart will be established for a number of cold cathode materials.

The program is divided into two concurrent phases, Phase A being concerned with the measurement of various pertinent properties of cold cathode materials outside of the tube environment, and Phase P involving the evaluation and life testing of selected cathodes in a crossed-field amplifier.

The first quarterly report of this contract (Technical Report ECOM 01698-1) contains a discussion of the objectives and plans for the over-all program. Quarterly Report No. 5 contains a description of the CFA test vehicles used in this program.

2. PHASE A - MATERIALS EVALUATION

2.1 Electron Bombardment Evaluation. During the present quarter, several samples were evaluated in the Electron Bombardment Vehicle (EBV). The effort on secondary emission ratio (δ) of high current-density electron bombardment (up to 0.75 A/cm^2) was measured as well as recovery with oxygen. These samples were as follows:

a. 300Å aluminum-oxide layer on 1100 aluminum (anodically oxidized) - 20 hour continuation of sample A-2.

b. Another anodized 1100 Al sample (like A-2) - sample A3 for 30 hours.

c. A nickel-cermet sample for 6 hours on the hot/cold EBV.

d. 300Å electron-beam-evaporated layer of alumina on Mo for 41 hours.

e. 300Å layer BeO on Be (anodically oxidized), 37 hours.

The following samples were prepared during the present quarter:

a. Four 300Å electron-beam-evaporated alumina on Mo samples for EBV.

b. Four Be samples for EBV. These were diffusion-bonded to copper. Two of these samples were anodically oxidized by the tartaric acid method to form a 300Å BeO layer on Be.

c. Eight beryllium-copper samples for EBV were machined.

d. Eight silver-magnesium samples for EBV were machined.

In addition several EBV gun units were assembled.

2.1.1 300Å Electron-Beam-Evaporated Alumina on Molybdenum. During a 41-hour period of electron bombardment evaluation, δ_{max} varied between 2.0 and 3.8 (Figure 1). In order to achieve 3.8 it was necessary to admit O_2. While O_2 was admitted to a pressure of 1.5×10^{-5} Torr and during electron bombardment at 0.15 A/cm^2 (corresponding to 3 ma), δ_{max} rose from 2.0 to 3.8. After the O_2 was pumped away, electron bombardment at 0.75 A/cm^2 (corresponding to 15 mA) caused δ_{max} to decrease from 3.8 to 2.2 in nine hours. Testing of this sample is continuing.

2.1.2 Anodized Beryllium - 300Å Oxide Layer. During a 37-hour period of electron bombardment evaluation, δ_{max} varied between 1.6 and 3.0 (Figure 2). O_2 at 1.5×10^{-5} Torr caused a significant increase in δ_{max}, particularly with 3 mA bombardment rather than with no bombardment. Perhaps some temperature increase is beneficial to surface reoxidation. After the O_2 was pumped away, δ_{max} decreased due to electron bombardment, 0.75 A/cm^2 causing a more rapid decrease than 0.15 A/cm^2.

2.1.3 Anodized Aluminum (Alloy 1100) - 300Å Oxide Layer. Sample A-2, reported in the 9th Quarterly, was continued for 19 hours (hours 55 to 74) under 0.5 A/cm^2 electron bombardment without O_2. During this period, δ_{max} remained essentially constant at 2.3.

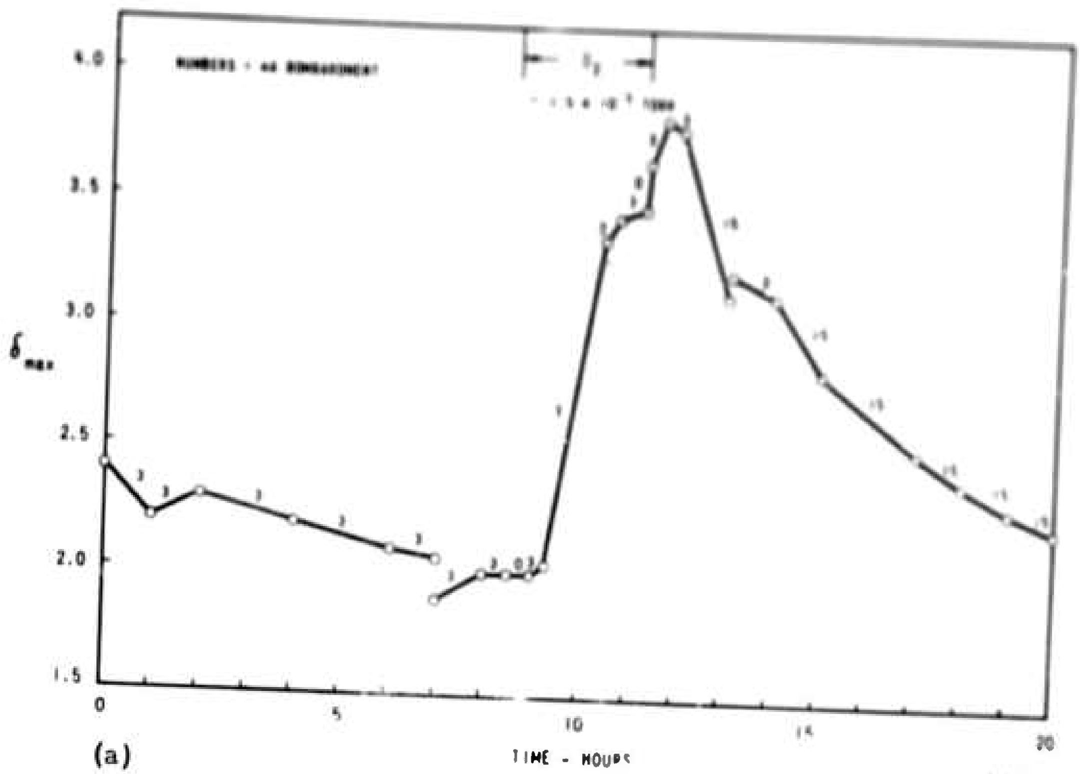
Another similar sample (A-3) was evaluated for a 30-hour period. δ_{max} remained at 1.5 during the initial 15-hour period of electron bombardment without O_2. Up to 0.75 A/cm^2 bombardment was employed. Then O_2 was admitted up to a pressure of 1.6×10^{-5} Torr. δ_{max} rose slightly to a value of 2.0. Further testing of this sample was discontinued due to the lack of response to O_2 usually observed.

2.1.4 Nickel-Cermet Sample in Hot/Cold EBV. Another nickel-cermet sample was installed in the Hot/Cold EBV. Thermal activation of the sample was attempted over a 5-hour period, during which it was at 900°C for two hours. The minimum value of δ_{max} was 1.5 and the maximum value was 1.8. Apparently the activation was not successful. The test was terminated due to a leak in the gun housing. The gun unit has been replaced and further EBV evaluation of a nickel-cermet sample will be attempted in the next quarterly period.

3. PHASE B - CFA TESTING

3.1 QKS1397 Test Vehicle

3.1.1 Model No. 8C. Cathode emission life-test evaluation was conducted on Model 8C during the report period, at a cathode-pulsed modulation test station. The cathode emitter consisted of 0.0005-inch aluminum deposited on an OFHC copper base. The cathode was 1.645 inches in diameter, 0.670 inch axial height for an emitter surface area of 22.4 sq. cm.



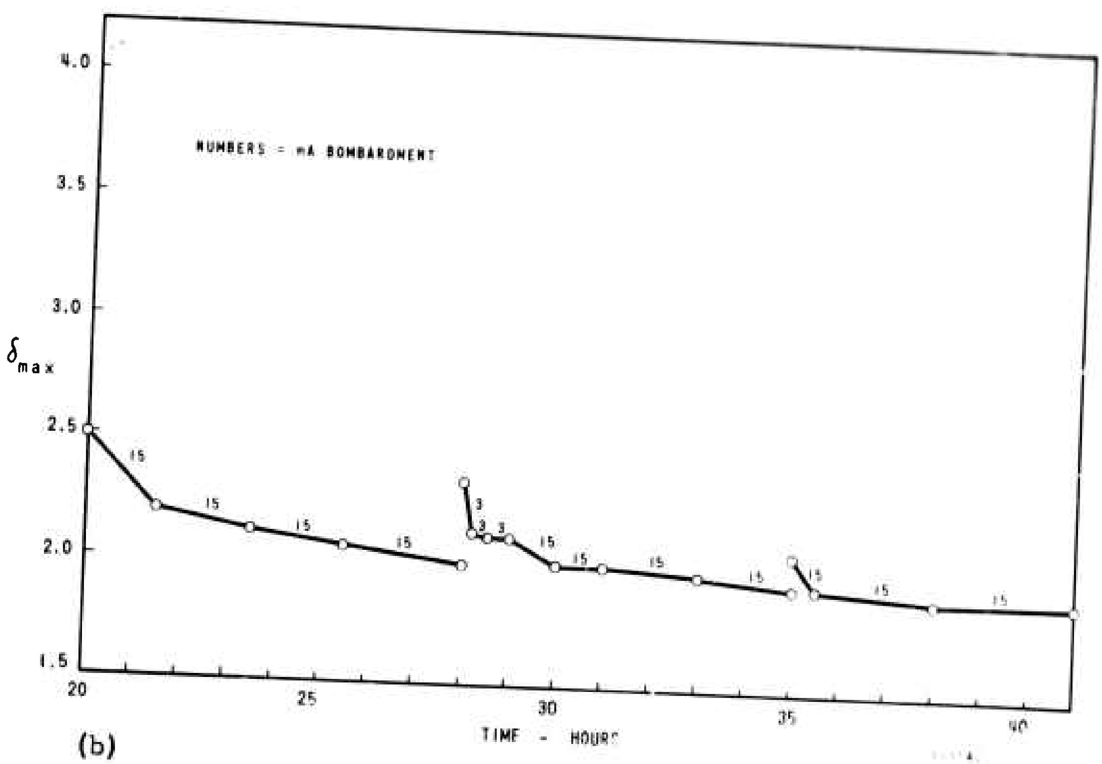


Figure 4 δ_{max} vs EBV Time for 300Å Al_2O_3 on Molybdenum

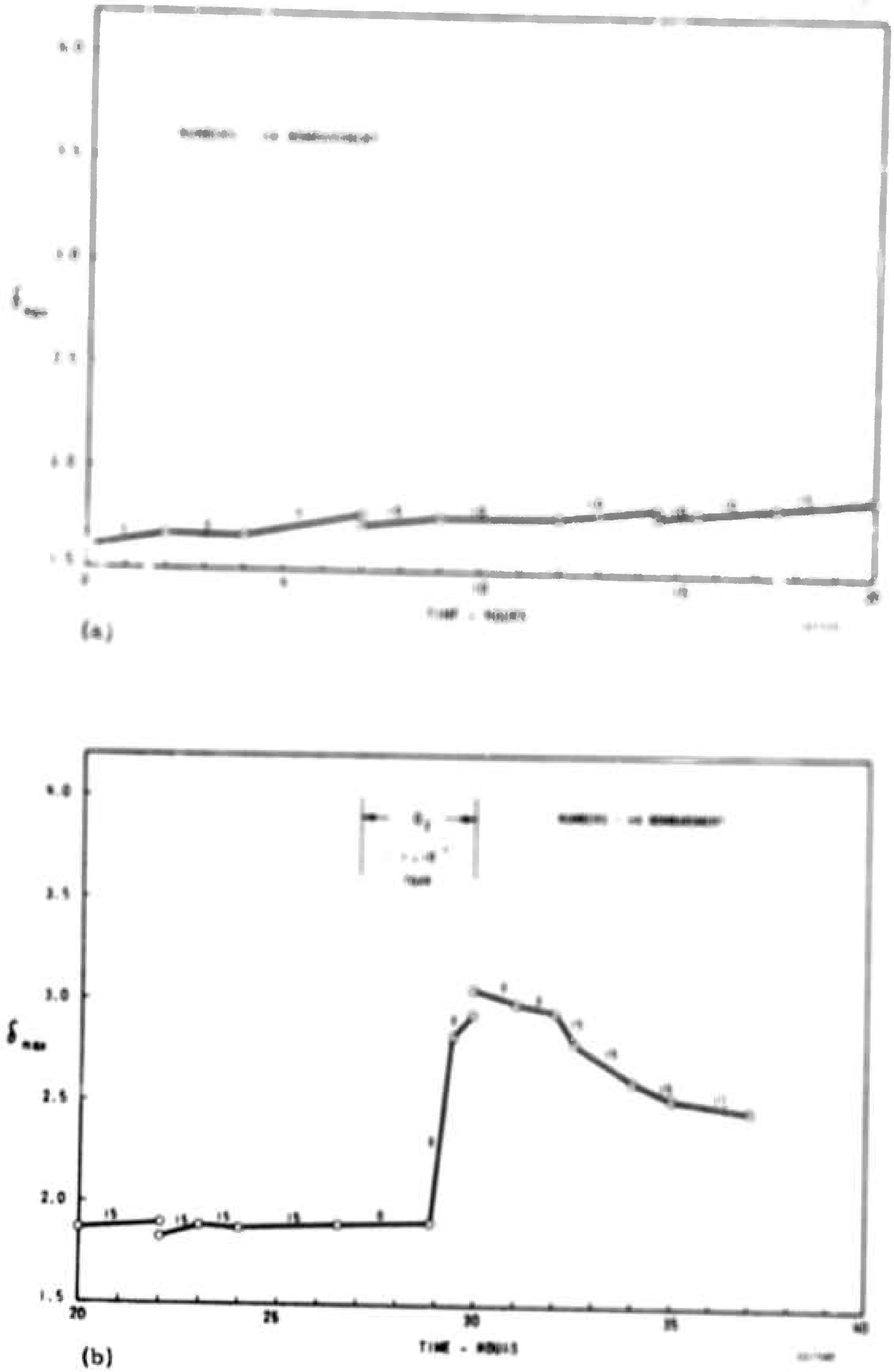


Figure 5 δ_{max} vs EBV Time for 300Å Anodized Beryllium

In Figure 3, the solid line shows the peak current, and the dashed line the oxygen-dispenser heater power, both as a function of time for the duration of life testing completed to date. The maximum current emission available is also indicated by X's as obtained at various times of the life test period.

Initially the operating peak current level was chosen at 56.5 amperes, at the following operating conditions:

D_u = 0.001
f_o = 3.3 GHz
P_{in} = 110 kW
P_o = 800 kW
e_b = 33 kV
B = 3000 gauss

This level of emission could not be maintained without use of the oxygen dispenser. The oxygen-dispenser heater power was therefore gradually increased to 60 watts, at which point the emission had recovered sufficiently for operation at the level initially selected.

In the period 18 - 22 hours of operating time, the driver-tube trigger amplifier became unstable, which caused the test vehicle to arc, with resultant loss of emission. After repairs and emission reconditioning by increasing the oxygen-dispenser heater power to 63 watts, life testing was continued at the initially selected peak-current level through the 72nd hour of operation. At this point the maximum peak current available had decreased to the operating current level.

The operating conditions were now changed to a duty factor of 0.002 and a frequency of 3.35 GHz. An immediate decline in the peak current available was observed, although it could be recovered by increasing the oxygen-dispenser heater power to 70 watts. However, operation at this heater-power level shortens the oxygen pellet life; the heater power was therefore restored within a short time to 63 watts.

After approximately 120 hours of operation, the test-vehicle trigger amplifier became erratic, which caused the tube to arc, with consequent loss of emission. The emission gradually recovered after repairing the trigger-amplifier unit. At 140 hours of operation, the emission was further increased by increasing the peak drive power to 125 kW. After about 10 hours of operation at this level, the drive power was restored to 110 kW, with the resultant continual decrease in peak-current emission.

At 182 hours of operating time the oxygen-dispenser power supply leads were shortened by eliminating all clip leads. This apparently reduced the lead resistance, and thereby increased the power available for heating the oxygen-dispenser pellet. The peak-current emission available showed an immediate increase to 56 peak amperes, but again could not be maintained. At the end of the report period (223 hours) the peak-current emission appeared to have settled near 40 amperes.

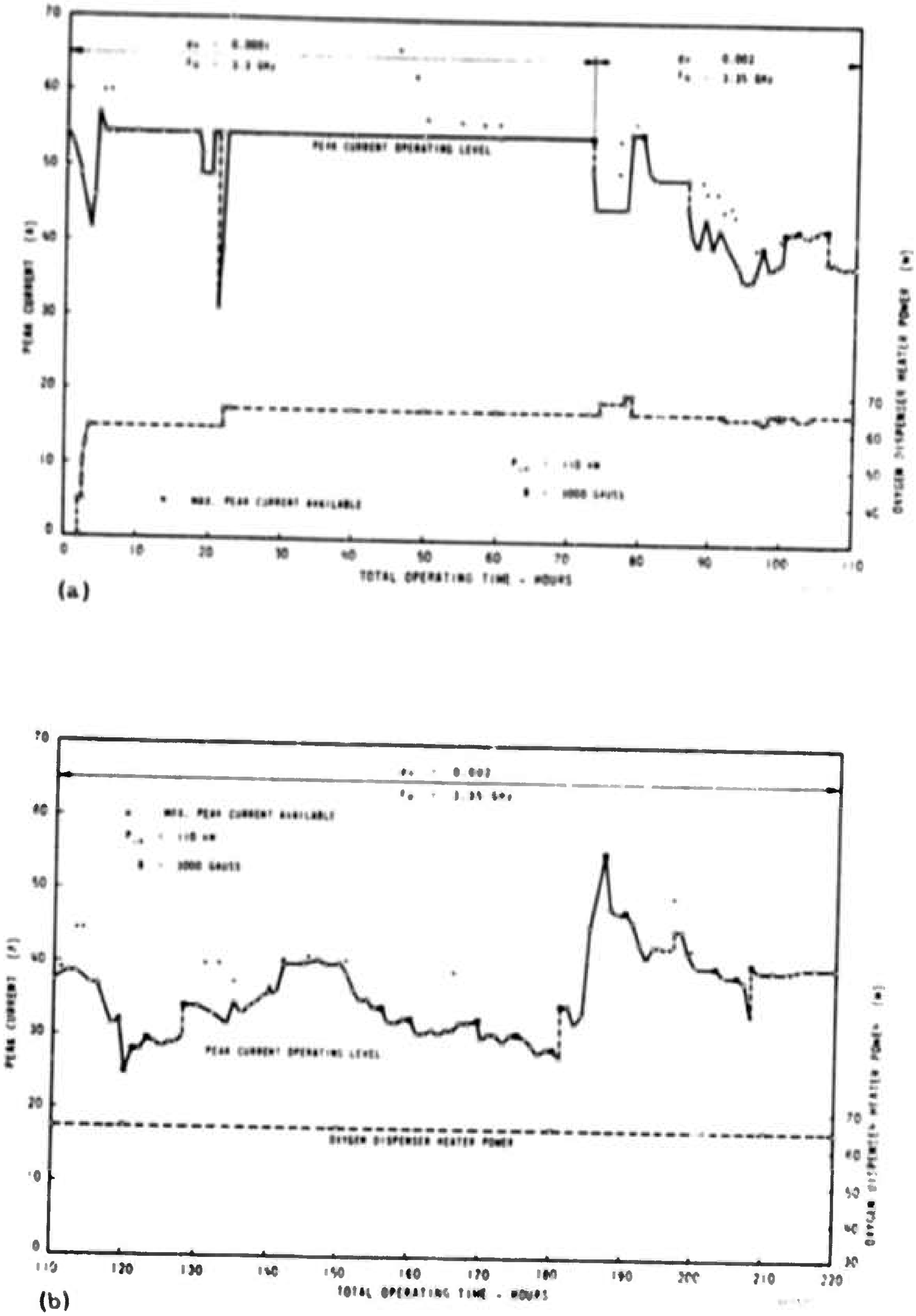


Figure 10 QKS1397 No. 8C - p_{in} = 110 kW, B = 3000 Gauss
0.0005 in. Evaporated Al on Cu Emitter

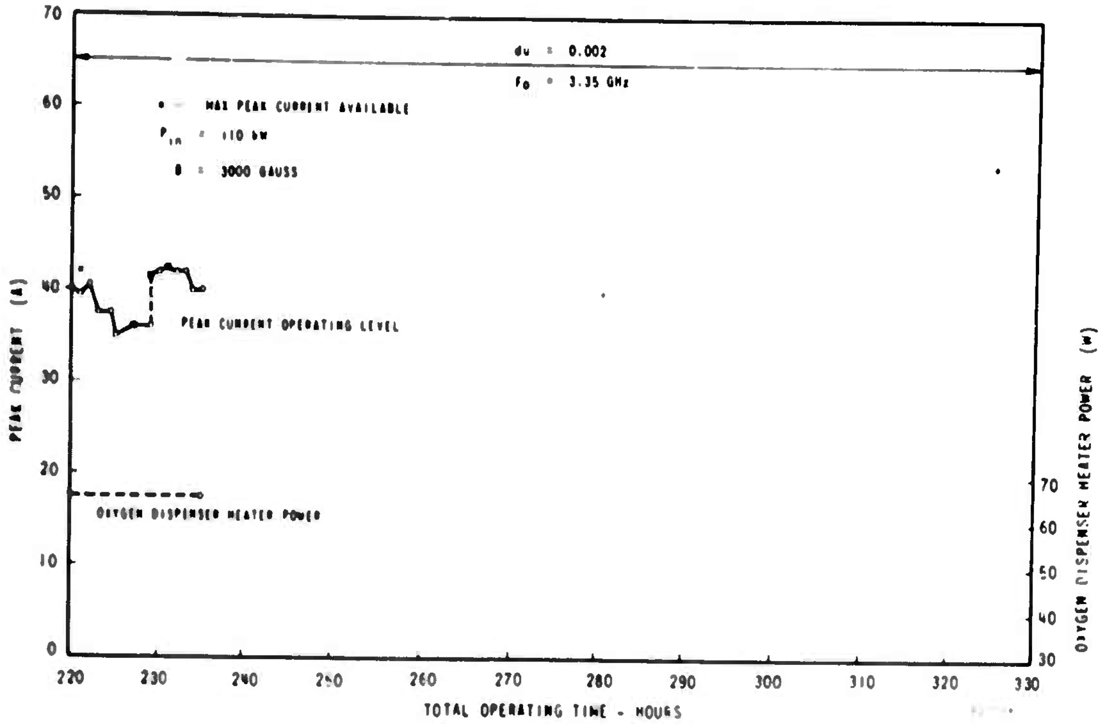


Figure 3 - Sheet 2. QKS1397 No. 8C - p_{in}=110 kW, B=3000 gauss

4. CONCLUSIONS

4.1 Phase A - Materials Evaluation.

a. 300Å oxide layers of electron-beam-evaporated alumina on molybdenum, anodized beryllium, and anodized aluminum, show generally similar behavior in terms of beneficial response to oxygen and deterioration of δ due to electron bombardment at 0.75 A/cm^2.

b. A possible interpretation of some of the data reported above is that some elevation of temperature above room temperature may be beneficial in the response of δ to O_2 for a beryllium or aluminum sample.

4.2 Phase B - CFA Testing. Operation of the QKS1397 CFA test vehicle for more than 200 hours has shown that the available emission from a deposited aluminum cold cathode appears to have stabilized near 40 amperes, at a 0.002 duty factor. At 0.001 duty factor, approximately 70 hours of operation was obtained at a peak current level of 54.5 amperes. Activation of the O_2 dispenser was required throughout the test period to maintain the cathode emission.

5. PROGRAM FOR NEXT INTERVAL

5.1 Phase A

a. Continue testing of electron-beam-evaporated alumina on Mo sample.

b. Continue testing of anodized beryllium sample.

c. Test a new nickel-cermet sample.

d. Process Ag-Mg and Be-Cu samples for EBV.

e. Test the Ag-Mg and Be-Cu samples.

5.2 Phase B

a. Continue life testing of QKS1397 model 8C.

b. Rebuild the QKS1397 test vehicle with an impregnated tungsten cathode.

c. Accumulate additional operating life on the impregnated cathode in the QKS1194 test vehicle.

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13. ABSTRACT

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